Regional Trends in Helium Isotopes: Evidence for Deep Permeability in the Basin and Range

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RESEARCH OBJECTIVES

The Basin and Range Province of western North America is characterized by an anomalous geothermal gradient that has created a vast region of exceptional potential for geothermal energy development. However, first-order exploration techniques are difficult to apply: by the time deep fluids emerge at the surface, they have re-equilibrated at lower temperatures, overprinting chemical and isotopic compositions that might otherwise provide evidence for deeper high-temperature reservoirs. In essence, the geothermal systems are "hidden." This project maps regional trends in helium isotopic compositions that may detect local zones of deep permeability where surface waters, penetrating deep in the crust, can be heated to form potential geothermal systems.

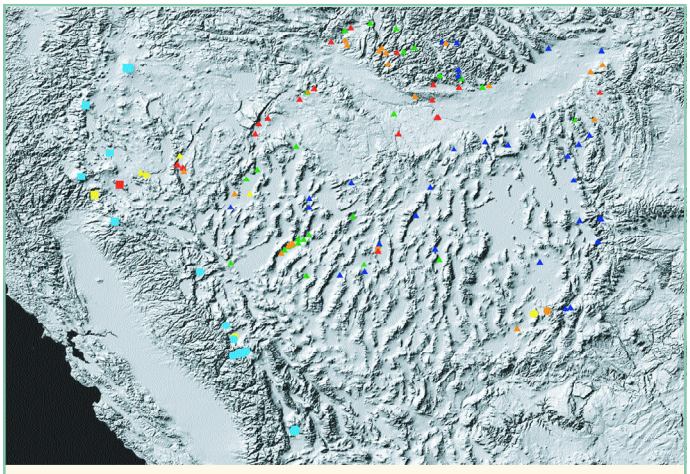

Figure 1. Shaded relief map of the Basin and Range (BR) and nearby surrounding areas. Locations are shown for hot spring and hot well samples for the BR, the Snake River Plain (SRP), the Idaho Batholith (IBL), and for some of the Cascade volcanoes (CV). Some geographical locations are identified. Data from this study, Welhan et al. 1988, and Jenkins, unpublished data (used with permission).

Symbols are shape and color coded to indicate magnitude of $^3He/^4He$ ratio and heat source:
1. Filled circles: BR magmatic heat source or possible BR magmatic heat source.
2. Filled triangles: BR extensional heat source. The samples from the SRP and IBL are included in this catagory until a better assessment of their heat source can be made.
3. Filled squares: CV magmatic heat source.
4. Filled diamonds: BR/CV transitional - unclear heat source: a geothermal well and two springs near Canby, CA.

Color coding is as follows:
Blue ≤ 0.3 Ra; 0.3 > Green ≤ 0.6 Ra; 0.6 > Orange ≤ 1.0 Ra; 1.0 > Red ≤ 2.0 Ra; 2.0 > Yellow ≤ 3.0 Ra; Cyan > 3.0 Ra.

APPROACH

The focus of the project is the relationship between known Basin and Range geothermal resources and the presence of fault-hosted, deep, permeable fluid-flow pathways, as identified by anomalous helium isotopic compositions in surface fluids. The anomalies are defined as high helium-isotopic ratios relative to a regional trend. Helium isotopes are of particular interest because they provide unequivocal evidence for the presence in crustal fluids of mantle-derived volatiles that can only be acquired by deep fluid circulation.

ACCOMPLISHMENTS

We have found that exceptionally high helium-isotopic compositions (~3-6 Ra—Ra is the ratio in air) are confined to the western margin of the Basin and Range (Figure 1) coinciding with a zone of active volcanism, extending along the eastern Sierra into the Cascade volcanic complex of northern California and Oregon. Moving east, there is a general decline to values as low as ~0.1 Ra. Superimposed on this trend are localized zones of high helium-isotopic compositions (e.g., DV, DIV, BRD). A detailed study of one of these "He-spikes" (DV, Dixie Valley) found that high ratios were restricted to fluids emerging directly from an active high-angle normal fault that hosts one of the most successful geothermal fields in Nevada. The high ratios require deep permeability consistent with the presence of high-temperature exploitable fluids rising through the fault. The other "He-spikes" occurring throughout the Basin and Range may also indicate deep permeability and high potential for geothermal development.

SIGNIFICANCE OF FINDINGS

Deep permeable pathways are a necessity in the development of viable nonvolcanic geothermal resources in the Basin and Range. The deep pathways provide access to high temperature and can host fluid convection cells. Helium isotopes may provide the best and perhaps only tool for detecting faults with deep and high-enough permeability to develop economic geothermal systems.

RELATED PUBLICATIONS

Kennedy, B.M. and M.C. van Soest, A helium isotope perspective on the Dixie Valley, Nevada hydrothermal system. Geothermics (submitted), 2005.

Kennedy, B.M. and M.C. van Soest, Regional and local trends in helium isotopes, Basin and Range Province, Western North America: Evidence for deep permeable pathways. Geothermal Resources Council, Trans (submitted), 2005.

ACKNOWLEDGMENTS

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